ELECTRICITY FOR THE TECHNICAL STUDENT

STAGE 1 THEORY

STUDENT MANUAL

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INDEX

CHAPTER 1

ELECTRON THEORY

MATTER

The universe consists of what is known as matter. This matter may exist as either a solid, a liquid, or a gas. Matter is made from elements or a combination of elements. The state of matter depends on its temperature and pressure at a given time, for example, H_2O (water) may exist as ice, water or steam. Most solid metals may be liquified if their temperature is increased sufficiently, while certain gases may be liquified by increasing their pressures. The smallest part of an element that can exist on its own is called an atom. Scientists are still debating the actual structure of the atom, so only the known facts which are relative to this course will be discussed in this book.

The typical atom has a solid centre called the nucleus, the main part of which are neutrons and protons. These are approximately equal in mass, but differ in that the neutrons exhibit no electrostatic charge while the protons are given positive electrostatic charge. Orbiting around the nucleus are electrons. These have practically zero mass compared with the nucleus and are said to exhibit negative electrostatic charge. The atomic structure may be compared with the solar system.

The electrons rotate in a three dimensional plane. (Figure 1.1).

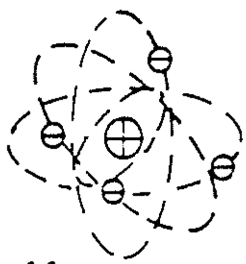

Figure 1.1

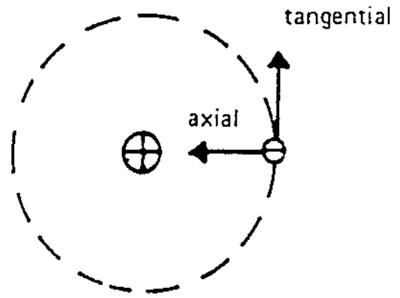

Figure 1.2

The student commencing this course is well aware that the planets rotate around the sun at high velocities, but are held in their orbits by a force of attraction to the sun. Similarly the rotating electron is held in its orbit around the nucleus, by a force of attraction which is stated in the Electrostatic Laws of Charge. These are -

(a) unlike charges attract each other.

(b) like charges repell each other.

The positively charged nucleus exerts a force of attraction on the negatively charged electron, which is balanced by the tangential force due to the velocity of the electron. Thus the electron orbits at a fixed distance from the nucleus. (Figure 1.2).

1.1 ENERGY LEVELS IN ATOMS

Natural elements vary only in the equal number of protons and electrons in their atomic structure. Hydrogen has one proton and one electron. Helium has two protons and two electrons. The electrons rotate within fixed limits from the nucleus, depending on the number of electrons in the atom. These fixed distances form what is known as energy rings, shells, levels or bands. Between these shells, of which there is a maximum of seven, electrons cannot exist. The areas between the shells are called forbidden bands. The shells are designated by the letters - K, L, M, N, O, P, Q. (Figure 1.3)

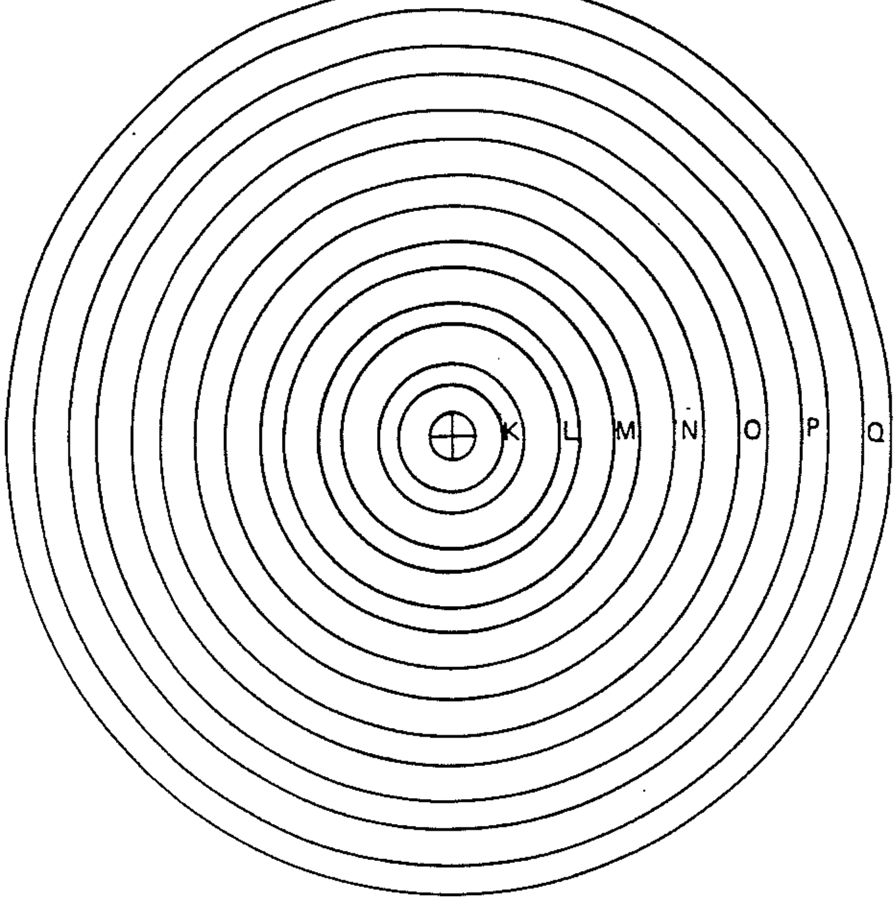

Figure 1.3

For ease of understanding the illustration is drawn in a two dimensinnal plane. The shells have fixed minimum and maximum diameters depending on their distance from the nucleus. Each complete sheil contains one or more sub-shells, the first four being illustrated in Figure 1.4.

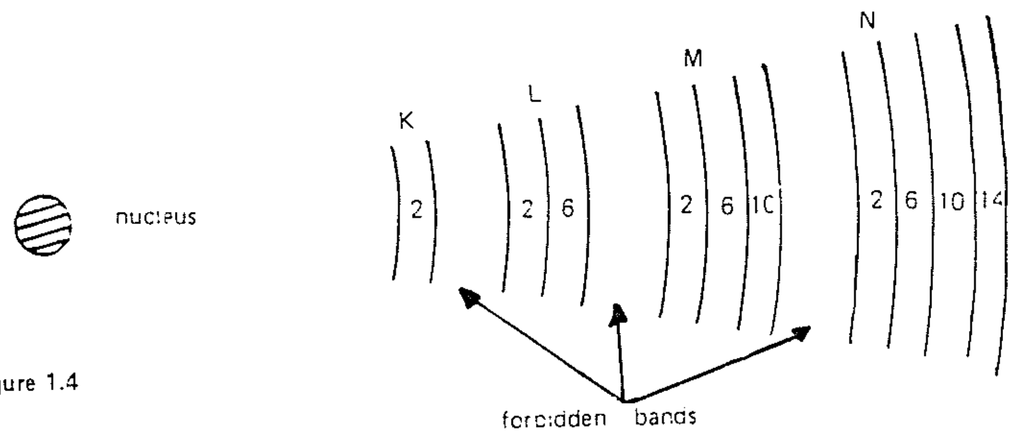

Figure 1.4

The maximum number of electrons each sub-shell may contain is shown, while the maximum number of electrons each major shell may contain can be found by adding the number of electrons in each sub-shell.

1.2 ELECTRON MOVEMENT FROM SHELL TO SHELL

Electrons possess energy by virtue of their motion. To shift from one energy level to another, the electrons must absorb or release discrete amounts of energy, known as quantas. A quantum of energy is the least unit amount of energy which can be considered in the process. Furthermore, quanta must exist as whole numbers, fractions of a quanta do not exist. If the energy required to shift an electron from one level to another was three quanta units, an energy level of two quanta units would produce no shift. If the energy level was increased to three quanta units, the electron would shift abruptly from one level, across the forebidden band, into the next level. The further the major shell containing the electron is from the nucleus, the lower the amount of quanta units required to shift it from one shell to another.

1.3 IONISATION

The electrostatic charge on a complete atom is zero, or the atom is said to be electrically neutral. In the neutral state the number of electrons (−charge) equals the number of protons (+ charge). The heavy protons cannot be removed from the nucleus by natural means, but the lighter electron in the outer, or valance shell, may move away from the nucleus, either naturally or under the influence of an external force. If this occurs there will be one more positive charge than negative charge in the atom, so that the atom exhibits an overall positive charge. Similarly, an electron that has escaped from its atom may orbit temporarily around a neutral atom, causing the atom to exhibit an overall negative charge.

When a neutral atom gains or loses an electron it is said to be ionised. (Figure 1.5).

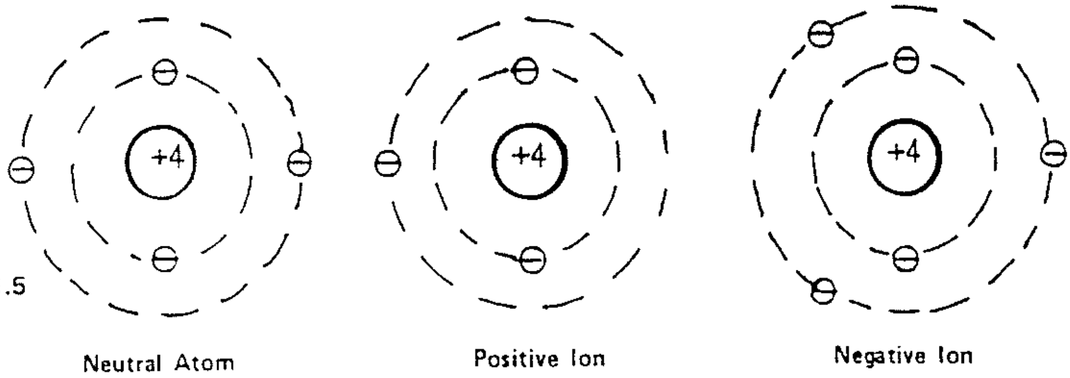

Figure 1.5

An ion will always attempt to revert to its neutral state.

1.4 METHODS OF PRODUCING IONS

The energy required to shift electrons away from the influence of the nucleus may be obtained from many different sources. Some of the more common of these are -

(a) Heat

When heat, which is a form of energy, is absorbed by a solid, the energy content of the electrons in the solid is increased. If sufficient energy is imparted to the electrons on the surface of certain solids, these electrons will actually leave the surface of the solids for a time and form a cloud of electrons. This is known as **thermionic emission**. If the electrons lose the extra energy they will then return to their normal orbit in the solid. (Figure 1.6)

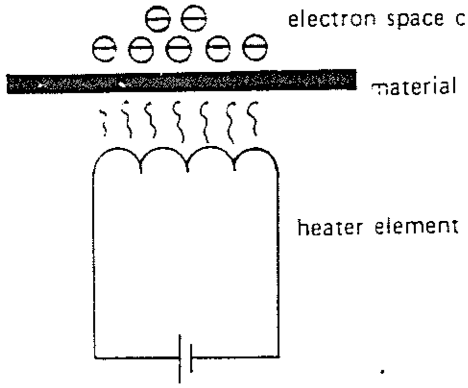

Figure 1.6

(b) **Collision**

Electrons released from the influence of their nuclei may be accelerated to very high velocities. This increases the energy of the electron. If a high velocity electron collides with a gas molecule it may dislodge an electron from the molecule, thus creating a gas ion. This type of ionisation is called **gas discharge.** (Figure 1.7)

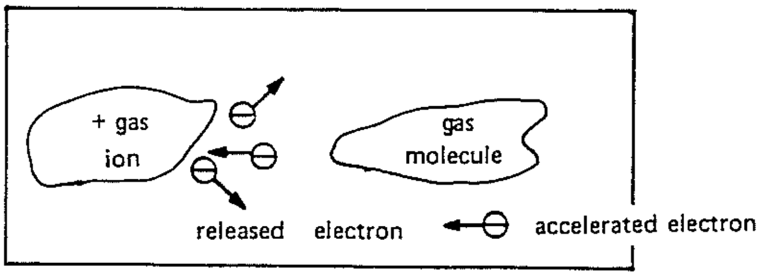

Figure 1.7

(c) **Bombardment**

High velocity electrons may also be directed at certain materials. When the high velocity electrons strike the surface of these materials, electrons may be released from the surface of the material. This is known as **secondary emission**. (Figure 1.8).

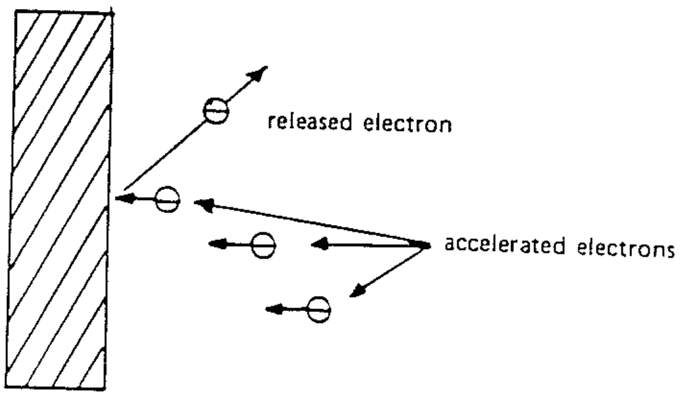

Figure 1.8

(d) Light

Light is a form of energy. The amount of energy contained in light depends on the wavelength of the light. If light of a suitable wavelength is focussed onto the surface of certain materials, electrons will leave the surface of that material. This is known as photo emission. There are many other methods some of which will be discussed in later chapters. (Figure 1.9).

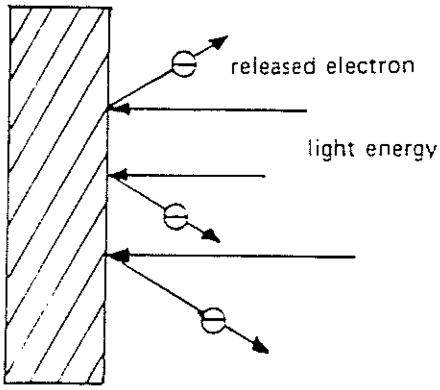

Figure 1.9

In many cases however, continuous ionisation occurs at room temperatures. At these temperatures, electrons in materials such as gold, silver, copper, aluminium and most other metals move at random throughout the materials. Because of this continuous movement, the electrons are known as free electrons and the atoms in the materials are consistantly changing from the neutral to the ionised state and back again. (Figure 1.10).

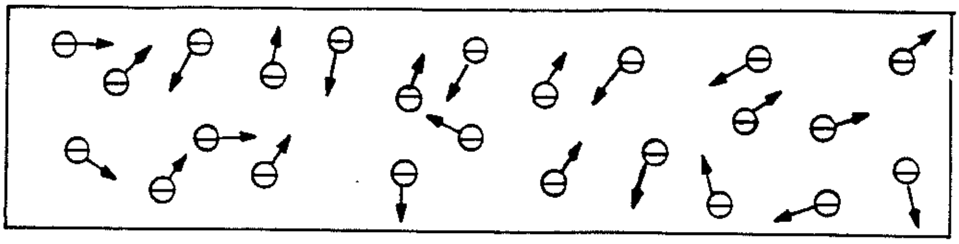

Figure 1.10

TUTORIAL 1.1

Transposition

Electrical theory involves a large number of equations because of the mathematical approach necessary to understand the topic. Equations consist of two sections, the left hand side of the equal sign, which is the unknown and is referred to as the subject, and the right hand side of the equal sign into which the known information is inserted and evaluated. In some problems the information is such that the unknown appears conveniently on the left hand side of the basic equation but in others the unknown appears on the right hand side of the equal sign. To solve the second type of problem the subject must be transferred so that it exists on its own on the left hand side of the equation. The transferring of the unknown from the right hand side to the left hand side is known as transposition.

There are many rules that can be applied to transposition but the main rules are as follows ·

(1) Whatever is done to one side of the equation must be done to the other side. If one side is divided by a certain quantity the other side must be divided by the same quantity. If an amount is added to one side of the equation the same amount must be added to the other side of the equation.

Example 1.1

$$x = yb + 6 \quad \text{—— (1)}$$

To remove 6 from the right hand side of equation (1) subtract 6 from each side

$$x - 6 = yb + 6 - 6$$
$$x - 6 = yb$$

(2) Always endeavour to form a straight line equation, that is, neither side is divided by any quantity.

Example 1.2

$$\frac{A}{B} = \frac{X}{Y} \quad \text{—— (2)}$$

To form a one line equation, cross multiply in equation (2)

$$\frac{A}{B} \times \frac{X}{Y}$$

$$AY = XB$$

(3) If there are no algebraic signs in the equation cover the quantity required as the subject and divide both sides with whatever is left on the side containing the subject.

Example 1.3

Make A the subject in the equation (3)

$$ABC = XYZ \quad \text{——(3)}$$

covering A leaves BC exposed on the left hand side. Divide both sides by BC.

$$\frac{ABC}{BC} = \frac{XYZ}{BC}$$

Cancelling the B's and C's on the left hand sides gives -

$$A = \frac{XYZ}{BC}$$

(4) If the subject is inside a set of brackets, transpose everything outside the brackets first, remove the brackets and then apply rules (1), (2) and (3)

Example 4

Make 'a' the subject in equation (4)

$$L = X\,(1 + ab) \quad \text{——(4)}$$

If the subject is within a set of brackets everything within the brackets is covered and both sides divided by what is left.

$$\frac{L}{X} = (1 + ab)$$

remove the brackets

$$\frac{L}{X} = 1 + ab$$

Remove the plus 1 from the right hand side by adding minus 1 to each sides

$$\frac{L}{X} - 1 = 1 + ab - 1$$

$$\frac{L}{X} - 1 = ab$$

To make 'a' the subject cover 'a' and divide both side by what is left.

$$\frac{\frac{L}{X} - 1}{b} = \frac{ab}{b}$$

cancelling the 'b' s gives

$$a = \frac{\frac{L}{X} - 1}{b}$$

TUTORIALS 1.1

Transpose the following equations as instructed.

(1) Make R the subject in $I = \frac{E}{R}$

(2) Make R_2 the subject in $\frac{R_1}{R_2} = \frac{\ell_1}{\ell_2}$

(3) Make A_1 the subject in $\frac{R_1}{R_2} = \frac{\ell_1 A_2}{\ell_2 A_1}$

(4) Make 'h' the subject in $W = mgh$

(5) Make E the subject in $P = \frac{E^2}{R}$

(6) Make t_c the subject in $R_h = R_c(1 + at_c)$

(7) Make I the subject in $\eta = \frac{Mgh}{EIt} \times \frac{100}{1}$

(8) Make t_f the subject in $H = mC_oC_r(t_f - t_c)$

(9) Make A the subject in $S = \frac{\ell}{\mu_o \mu_r A}$

(10) Make N the subject in $L = \frac{N^2 \mu A}{\ell}$